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(54) **CRANKCASE STRUCTURE FOR AN INTERNAL COMBUSTION ENGINE**

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F02B 75/22 (2006.01)
F02B 75/00 (2006.01)

(52) **U.S. Cl.** .... **123/195 R**; 123/195 AC

(58) **Field of Classification Search** .... 123/195 R, 123/195 AC; 180/219, 226, 230; 29/888.01
See application file for complete search history.

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(57) **ABSTRACT**

A crankcase structure of an internal combustion engine has a desirable shaft support achieved by maintaining the strength of a side wall of a crankcase at a high level without increasing the weight and the size of the internal combustion engine even when the internal combustion engine has an output shaft projecting from the crankcase. A crankcase structure has a crankshaft and a counter shaft that are rotatably supported on a partitioning plane of a crankcase. A main shaft is oriented in the fore-and-aft direction and is rotatably supported on opposed front and rear walls of either one of the upper and lower crankcases. An output shaft to be driven by a power of the counter shaft penetrates through the front and rear walls of one of the upper and lower crankcases by which the main shaft is not rotatably supported, and projects to the front and rear.

20 Claims, 6 Drawing Sheets

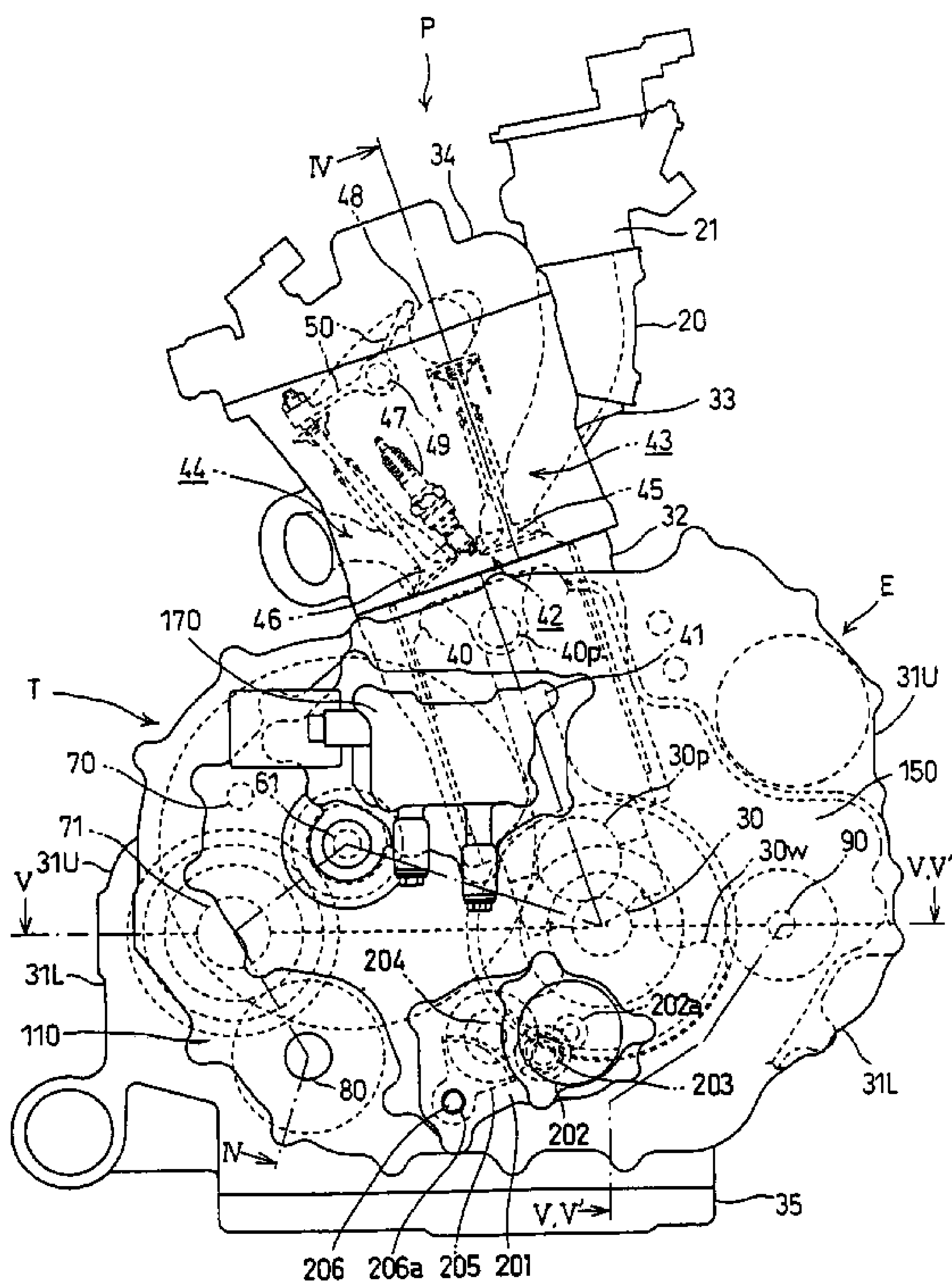

FIG. 1

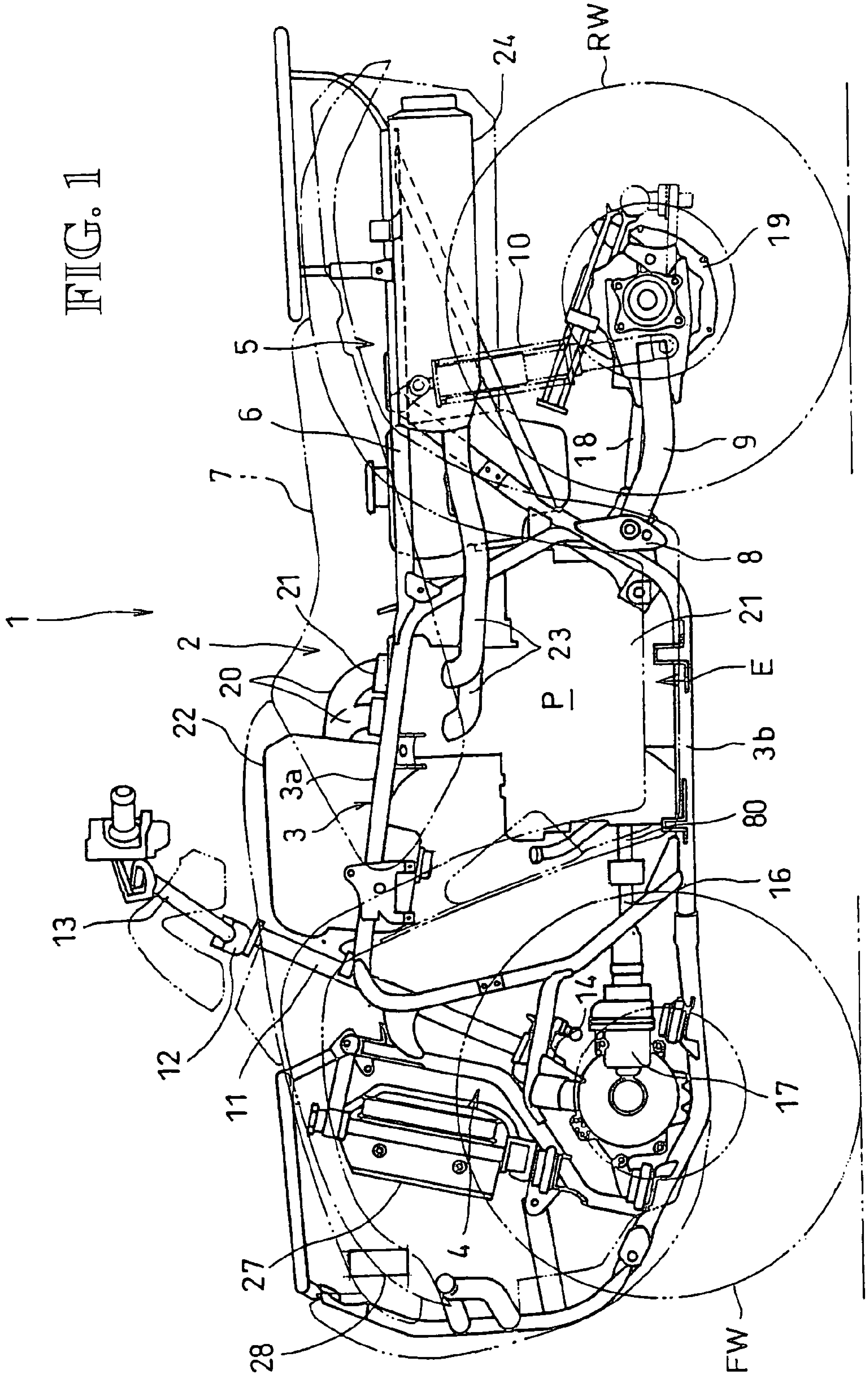
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FIG. 2

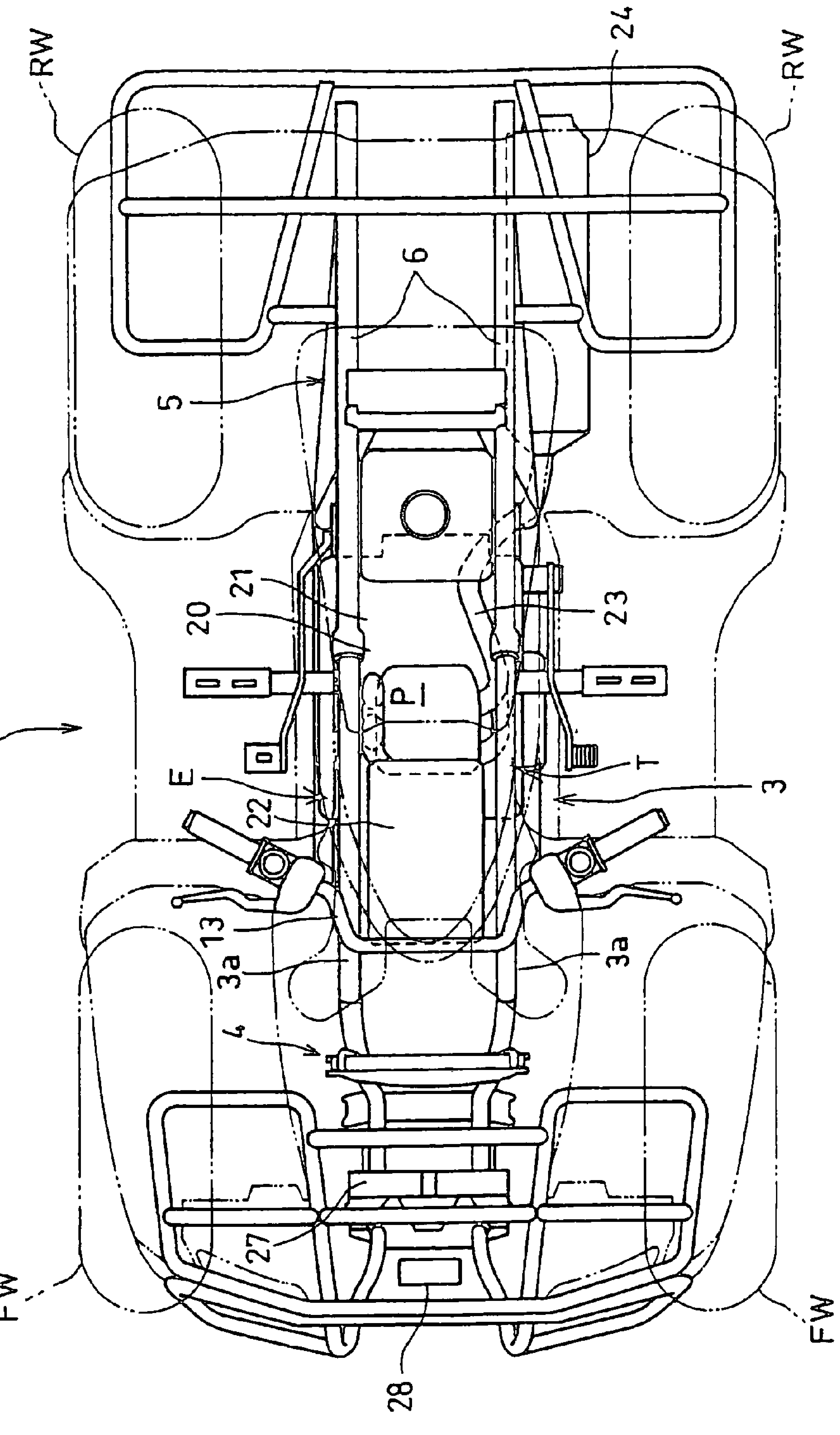
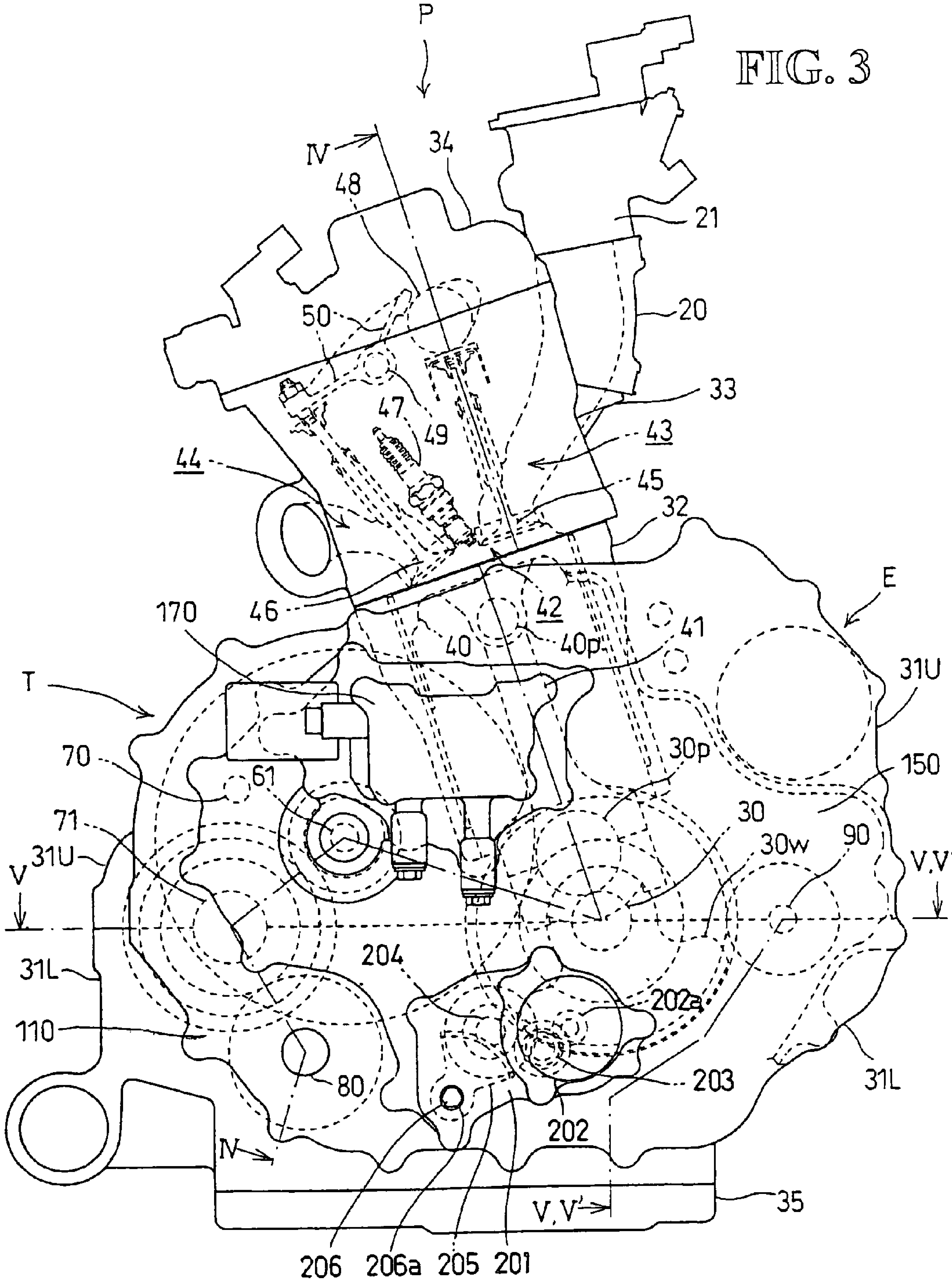


FIG. 3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IV
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33
43
44
45
32
46
42
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40p
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T
31U
70
61
30p
150
71
30
30w
90
31U
V
V,V'
31L
204
202a
110
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IV
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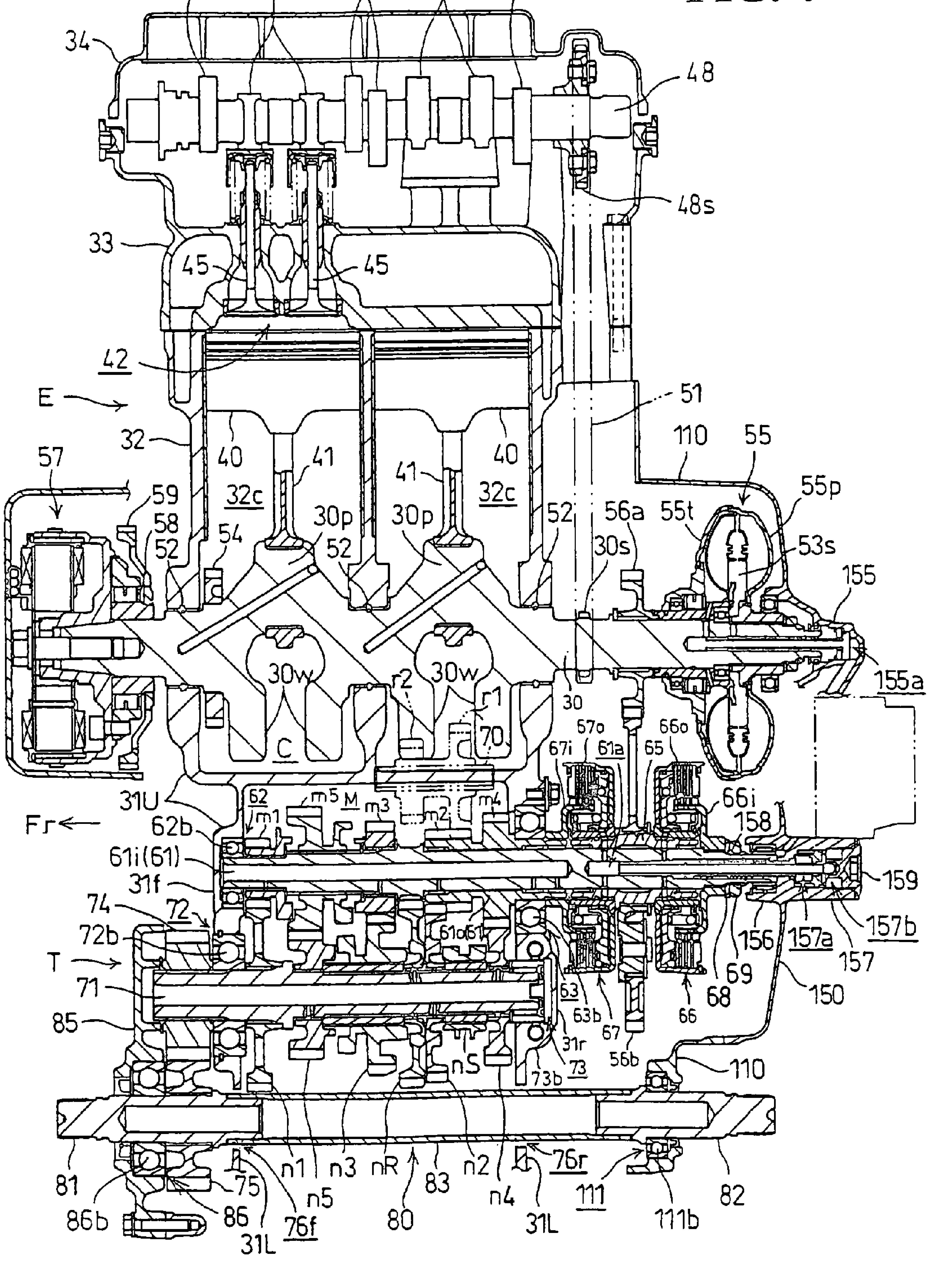
V,V'
206
206a
205
201

FIG. 4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66o
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T
63
68
150
71
63b
67
66
85
31r
56b
nS
73b
73
110
81
n1
n3
nR
83
n2
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n5
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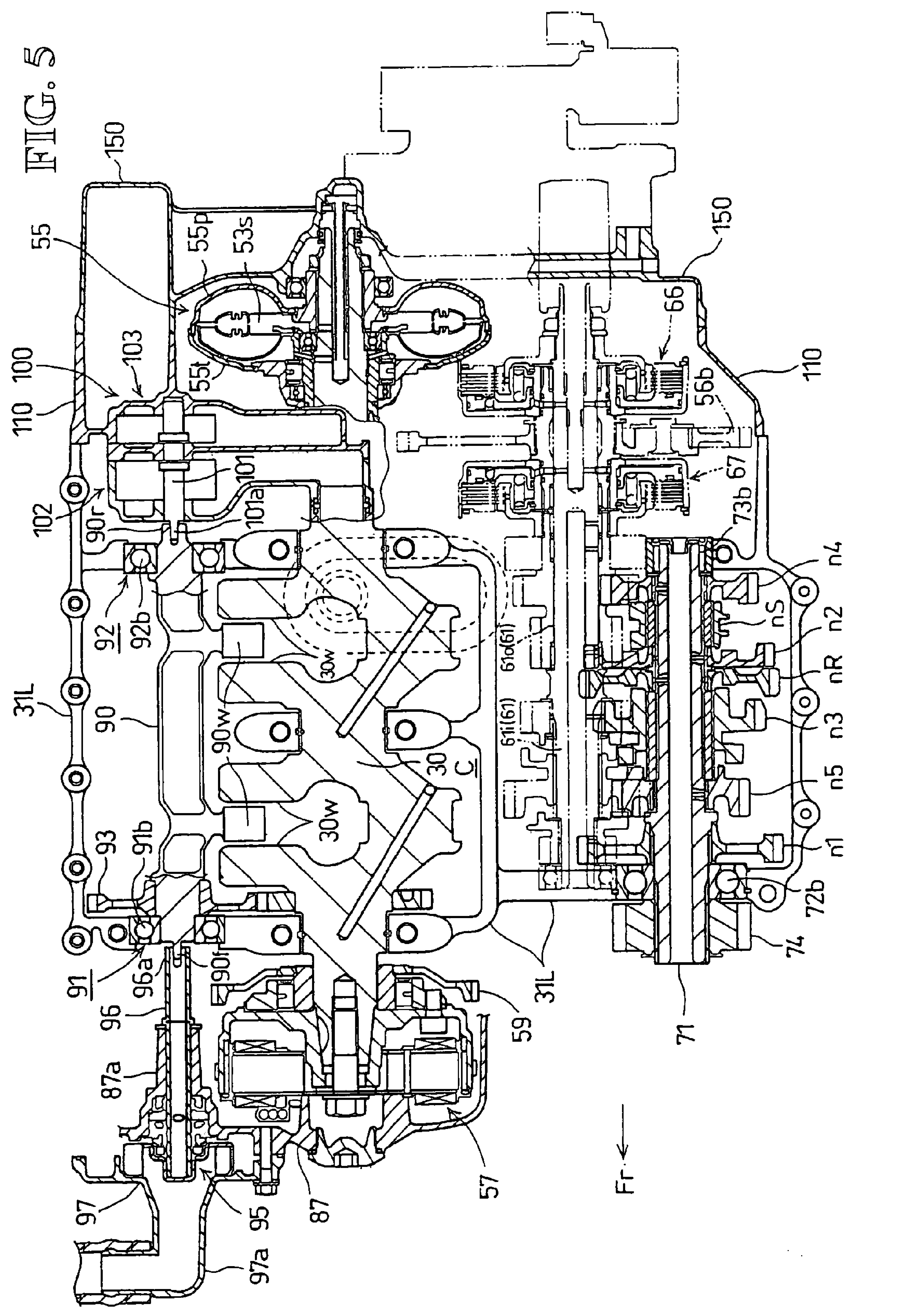
76f
31L

FIG. 5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C
61a(61)
61i(61)
66
56b
67
73b
n4
nS
n2
nR
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n5
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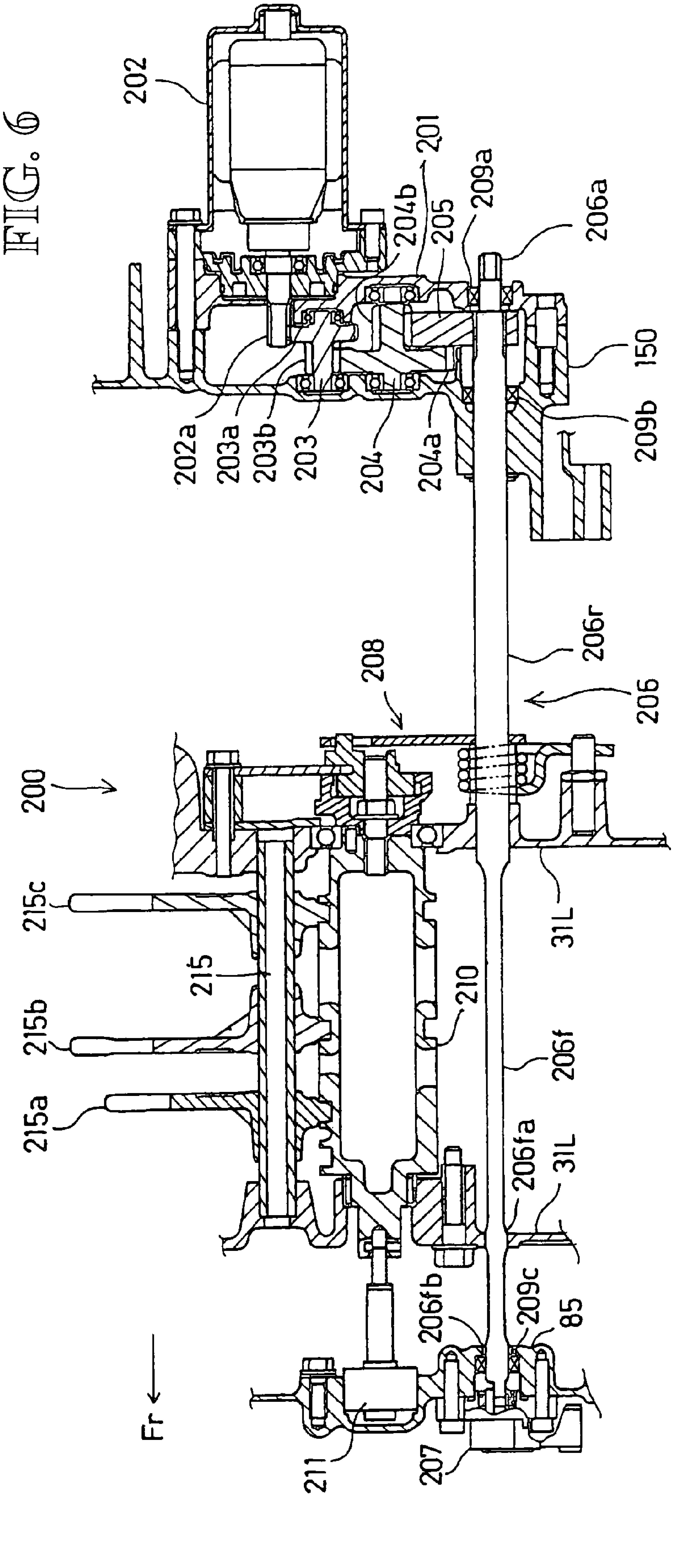
FIG. 6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31L
215c
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215b
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206f
215a
206fa
31L
206fb
209c
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CRANKCASE STRUCTURE FOR AN INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATIONS

This nonprovisional application claims priority under 35 U.S.C. §119(a) on Patent Application No. 2006-261277, filed in Japan on Sep. 26, 2006, the entirety of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a crankcase structure of an internal combustion engine.

2. Background of the Invention

In an internal combustion engine, a crank shaft and a counter shaft are rotatably supported on a partitioning plane by being sandwiched between an upper crankcase and a lower crankcase of a crankcase configured to have upper and lower halves. A main shaft is rotatably supported by the upper crankcase. Output members such as an output sprocket or an output gear are fitted to an end portion of the counter shaft projecting outward from the crankcase, to drive a rear wheel via a chain, or to drive an output shaft through meshing of gears.

An example of such internal combustion engine is disclosed in Japanese Patent No. 2670109. In a crankcase of an internal combustion engine disclosed in Japanese Patent No. 2670109, opposed left and right walls rotatably support the main shaft and the counter shaft. A rear wheel drive sprocket is fitted to the left end of the counter shaft which penetrates through the left wall. A left bearing opening on the left wall, which rotatably supports the left end of the main shaft via a bearing, is also an opening for removing the main shaft and hence has a large inner diameter.

The left wall of the crankcase, on which the bearing opening of a large diameter for the main shaft is formed, includes a bearing opening in which the counter shaft is rotatably supported via the bearing. The left bearing opening for supporting the counter shaft is located near the rear wheel drive sprocket and hence is subject to a large load. Therefore, the counter shaft must be rotatably supported robustly with a large bearing. However, the left bearing opening for supporting the main shaft is formed adjacent to the left bearing opening for supporting the counter shaft on the left wall of the crankcase.

As described above, the left bearing opening for supporting the main shaft has a large inner diameter for removing the main shaft, and the left bearing opening for supporting the counter shaft formed adjacent thereto also has to be formed to have a large inner diameter for fitting the large bearing. Therefore, it is difficult to maintain the strength of the left wall of the crankcase in the periphery of the rear wheel drive sprocket, which is to be fitted to the counter shaft.

In the internal combustion engine having the output shaft which projects from the front and rear of the crankcase for driving a front wheel or a rear wheel, the output shaft penetrates through the crankcase. Hence, the internal combustion engine tends to be increased in weight and size because the thickness is increased in order to secure the strength of the crankcase.

SUMMARY OF THE INVENTION

In view of the above problems, it is an object of the present invention to provide a crankcase structure of an internal combustion engine in which the strength of a side wall of a crankcase is maintained at a high level without increasing the weight and the size of the internal combustion engine to desirably support shafts, even when the internal combustion engine is provided with an output shaft that projects from the crankcase.

In order to achieve the object described above, a first aspect of the present invention is directed to a crankcase structure of an internal combustion engine in which a crankshaft and a counter shaft are rotatably supported on a partitioning plane of a crankcase including upper and lower halves oriented in the fore-and-aft direction. A main shaft oriented in the fore-and-aft direction is rotatably supported on opposed front and rear walls of either one of the upper and lower crankcases. An output shaft oriented in the fore-and-aft direction to be driven by a power of the counter shaft penetrates through the front and rear walls of one of the upper and lower crankcases by which the main shaft is not rotatably supported, and projects to the front and rear.

According to a second aspect of the present invention, a bearing opening for rotatably supporting the counter shaft via a bearing is formed on the one side wall at a position in the proximity of an output member provided at an end of the counter shaft projecting outward from the one of the opposed front and rear walls. A bearing recess for rotatably supporting one end of the main shaft via a first bearing is formed on the one side wall adjacent to the bearing opening for rotatably supporting the counter shaft. A bearing opening for rotatably supporting the other end of the main shaft via a second bearing is formed on the other side wall, which opposes the one side wall, so as to have an inner diameter larger than a transmission gear at the outer most end of the other end on the main shaft.

According to a third aspect of the present invention, the main shaft includes an inner cylinder and an outer cylinder rotatably fitted to a part of the inner cylinder. One end of the inner cylinder is rotatably supported by the bearing recess on the one side walls via the first bearing. The other end of the inner cylinder is rotatably supported together with the outer cylinder by the bearing opening on the other side wall via the second bearing.

According to a fourth aspect of the present invention, the main shaft is inserted into the bearing opening on the other side wall and the one end of the inner cylinder is rotatably supported by the bearing recess on the one side wall via the first bearing. Then, the second bearing is fitted between the outer cylinder rotatably fitted to a predetermined position of the inner cylinder and the bearing opening of the other side wall from the outside, so that the main shaft is assembled.

According to a fifth aspect of the present invention, a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder respectively are assembled respectively to the outside portion of the outer cylinder that projects outward from the bearing opening of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

According to the first aspect of the present invention, the crankshaft and the counter shaft are rotatably supported on the partitioning plane of the crankcase including the upper and lower halves oriented in the fore-and-aft direction. The main shaft oriented in the fore-and-aft direction is rotatably supported on the opposed front and rear walls of either one of the upper and lower crankcases. Therefore, the lateral width of the internal combustion engine may be reduced by arranging the crankshaft, the main shaft and the counter shaft at the respective apexes of a triangle. The output shaft penetrates through the front and rear walls of one of the upper and lower crankcases by which the main shaft is not rotatably supported, and projects to the front and rear. Therefore, the shaft support of the crank case may be dispersed. Hence, shaft support may be achieved desirably without upsizing the internal combustion engine.

According to the second aspect of the present invention, the bearing opening for rotatably supporting the other end of the main shaft via the second bearing is formed on the other side wall so as to have an inner diameter larger than the transmission gear at the outermost end of the other end on the main shaft. The bearing opening of the other side wall of the crankcase is used as an opening for assembling the main shaft. Therefore, the main shaft having the transmission gear group assembled thereto may be inserted into the bearing opening to achieve assembly of the main shaft and the assembleability of the main shaft may desirably be secured.

Therefore, it is not necessary to use the bearing recess for rotatably supporting the one end of the main shaft via the first bearing at one end as the opening for assembling the main shaft and hence the inner diameter may be reduced. Therefore, even when the bearing opening for rotatably supporting the counter shaft formed adjacent thereto is formed to have a large diameter for fitting the large bearing for resisting a load applied to the output members, the strength of the side wall of the crankcase in the periphery of the output members may be maintained at a high level.

According to the third aspect of the present invention, the one end of the main shaft of the inner cylinder having a small diameter is rotatably supported by the bearing recess of the one side wall via the first bearing. Therefore, the inner diameter of the bearing recess may be reduced. Hence, the strength of the side wall of the crankcase in the periphery of the output members provided on the counter shaft may be maintained at a higher level.

According to the fourth aspect of the present invention, the main shaft is inserted into the bearing opening of the other side wall and the one end of the inner cylinder is rotatably supported by the bearing recess on the one side wall via the first bearing. Then, the second bearing is fitted between the outer cylinder rotatably fitted to a predetermined position of the inner cylinder and the bearing opening of the other side wall from the outside, so that the main shaft is assembled. The assembling work of the main shaft may be desirably achieved.

According to the fifth aspect of the present invention, the pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder respectively are assembled respectively to the outside portion of the outer cylinder that projects outward from the bearing opening of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder. Therefore, the pair of transmission clutches may be assembled to the outer portion of the outer cylinder and the outer portion of the inner cylinder projecting outward from the crankcase. Hence, assembly of the transmission clutches may be achieved easily.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

FIG. **1** is a side view of a rough-terrain traveling vehicle in which a power unit according to an embodiment of the present invention is mounted with a vehicle body cover or the like removed;

FIG. **2** is a plan view of the same;

FIG. **3** is a rear view of the power unit;

FIG. **4** is a developed cross-sectional view of the power unit (taken along the line IV-IV in FIG. **3**);

FIG. **5** is a cross-sectional view of the power unit (taken along the lines V-V and V'-V' in FIG. **3**); and

FIG. **6** is a developed cross-sectional view of a transmission drive mechanism.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described in detail with reference to the accompanying drawings, wherein the same reference numerals will be used to identify the same or similar elements throughout the several views. It should be noted that the drawings should be viewed in the direction of orientation of the reference numerals.

Referring now to FIG. **1** to FIG. **6**, an embodiment of the present invention will be described. A side view of a rough-terrain traveling vehicle **1** in which a water-cooled internal combustion engine E according to this embodiment is mounted with a vehicle body cover or the like removed is shown in FIG. **1**. A plan view of the same is shown in FIG. **2**. In this embodiment, the front, rear, left and right are defined on the basis of the direction of travel of the vehicle.

The rough-terrain traveling vehicle **1** is a saddle type four-wheel vehicle, and a pair of left and right front wheels FW on which low-pressure balloon tires for rough-terrain are mounted and a pair of left and right rear wheels RW on which the same balloon tires are mounted are suspended in the front and rear of a vehicle body frame **2**.

The vehicle body frame **2** is configured with a plurality of types of steel material joined together. The vehicle body frame **2** includes a center frame portion **3**, on which a power unit P having the internal combustion engine E and a transmission T provided integrally in a crankcase **31** is supported. A front frame portion **4** is connected to the front portion of the center frame portion **3** for suspending the front wheels FW. A rear frame portion **5** is connected to the rear portion of the center frame portion **3** and has a seat rail **6** for supporting a seat **7**.

The center frame portion **3** includes: a pair of left and right upper pipes **3***a* and a pair of left and right lower pipes **3***b*. The upper pipes **3***a* each substantially form three sides by being bent downward at a front and rear thereof. The lower pipes **3***b* each substantially form one side to form substantially a rectangular shape in side view. The left and right pipes are connected by a cross member.

Swing arms **9** whose front ends are supported rotatably via a shaft by pivot plates **8** fixed to portions of the lower pipes **3***b* extend obliquely upward at the rear end thereof. Rear cushions **10** are provided between the rear portion of the swing arms **9** and the rear frame portion **5**. The rear wheels RW are suspended by rear final reduction gear units **19** provided at the rear ends of the swing arms **9**.

A steering column **11** is supported at the lateral center of the cross member extending between the front end portions of the left and right upper pipes **3***a*. A steering handle **13** is connected to the upper end portion of a steering shaft **12** steerably supported by the steering column **11**. The lower end portion of the steering shaft **12** is connected to a front wheel steering mechanism **14**.

The internal combustion engine E of the power unit P is a water-cooled two-cylinder internal combustion engine and is mounted to the center frame portion **3** with a crankshaft **30** oriented in the fore-and-aft direction of a vehicle body, that is, in a so-called vertical posture.

The transmission T of the power unit P is arranged on the left-hand side of the internal combustion engine E. An output shaft **80** oriented in the fore-and-aft direction projects toward the front and rear from the transmission T at a position which is displaced toward the left. Therefore, a rotational force of the output shaft **80** is transmitted from the front end of the output shaft **80** to the left and right front wheels FW via a front drive shaft **16** and a front final reduction gear unit **17**, and is transmitted from the rear end thereof to the left and right rear wheels RW via rear drive shafts **18** and the rear final reduction gear units **19**.

A radiator **27** is supported in the front frame portion **4** of the vehicle body frame **2**, and an oil cooler **28** is disposed in front thereof.

Referring to FIG. **3**, which is a rear view of the power unit P, the crankcase **31** that contains the internal combustion engine E and the transmission T of the power unit P in the interior thereof has a vertically divided structure divided into upper and lower halves, that is, an upper crankcase **31**U and a lower crankcase **31**L, along a plane including the crankshaft **30**.

A cylinder block portion **32** formed integrally with the upper crankcase **31**U at the upper portion thereof with two cylinder bores **32***c* arranged in series are formed so as to incline slightly toward the left and extend upward. A cylinder head **33** is placed on the top of the cylinder block portion **32**. The cylinder head **33** is covered with a cylinder head cover **34**.

On the other hand, an oil pan **35** is attached to the bottom of the lower crankcase **31**L.

Curved air-intake pipes **20** extending substantially upward from a right wall of the cylinder head **33** are connected to an air cleaner **22** arranged above the internal combustion engine E with the intermediary of a throttle body **21**. A curved exhaust pipe **23** extending rearward from a left wall of the cylinder head **33** is connected to an exhaust muffler **24** attached on the left-hand side of the rear frame portion **5**.

Referring now to FIG. **3** and FIG. **4**, pistons **40** are fitted to the two cylinder bores **32***c* of the cylinder block portion **32** so as to be capable of reciprocating. Crank pins **30***p* between crank webs **30***w*, **30***w* of the crankshaft **30** and piston pins **40***p* of the pistons **40** are connected by connecting rods **41**. Therefore, a crank mechanism is configured.

In the cylinder head **33**, each cylinder bore **32***c* includes: a combustion chamber **42** opposing the pistons **40**; an air-intake port **43** opening into the combustion chamber **42** and extending rightward and upward so as to be opened and closed by a pair of air-intake valves **45**; exhaust ports **44** extending forward so as to be opened and closed by a pair of exhaust valves **46**; and ignition plugs **47** mounted thereto so as to be exposed into the combustion chamber **42**. The air-intake pipes **20** are connected to the air-intake ports **43**.

The upper ends of the air-intake valves **45** come into abutment with air-intake cam lobes **48***i* of a camshaft **48**, which is rotatably supported by the cylinder head **33** via a shaft. One end of a rocker arm **50** rotatably supported by a rocker arm shaft **49** via a shaft comes into abutment with exhaust cam lobes **48***e* of the camshaft **48**. The upper ends of the exhaust valves **46** come into abutment with the other ends of the rocker arms **50**.

Therefore, the air-intake valves **45** and the exhaust valves **46** open and close the air-intake ports **43** and the exhaust ports **44** synchronously with the rotation of the crankshaft **30** by the camshaft **48** at a predetermined timing. In order to do so, the camshaft **48** is fitted with a cam sprocket **48***s* at the rear portion thereof. A timing chain **51** is wound between a drive sprocket **30***s* fitted to the portion of the crankshaft **30** near the rear end portion thereof and the cam sprocket **48***s* (see FIG. **4**), so that the camshaft **48** is driven to rotate at half a revolving speed of the crankshaft **30**.

The crankshaft **30** is rotatably supported by being clamped between the upper crankcase **31**U and the lower crankcase **31**L via a plane bearing **52**. As shown in FIG. **4**, the rear portion of the crankshaft **30** that projects rearward from a crank chamber is formed with the drive sprocket **30***s*. A primary drive gear **56***a* is provided on further rear ends thereof via a fluid coupling **55** as a fluid joint. The fluid coupling **55** includes a pump impeller **55***p* fixed to the crankshaft **30**, a turbine runner **55***t* opposed thereto, and a stator **53***s*.

The primary drive gear **56***a* is joined with the turbine runner **55***t*, which is rotatable with respect to the crankshaft **30**. The power from the crankshaft **30** is transmitted to the primary drive gear **56***a* via hydraulic oil. The primary drive gear **56***a* meshes with a primary driven gear **56***b*, which is rotatably supported by a main shaft **61**, described later, and transmits the rotation of the crankshaft **30** to the main shaft **61** side.

On the other hand, a starting driven gear **59** is supported by the front side portion of the crankshaft **30** projecting forward from a crank chamber C via an AC generator **57** and a one way clutch **58**. A balancer shaft drive gear **54** is fitted to a portion of the crankshaft **30** extending along the inner surface of the front wall of the crank chamber C.

A transmission chamber M is defined by being partitioned by a partitioning wall in the left side of the crank chamber C that accommodates the crank webs **30***w* of the crankshaft **30**.

A transmission gear mechanism **60** accommodated in the transmission chamber M is a constantly engaging gear mechanism, in which the main shaft **61** is supported by the upper crankcase **31**U at a position leftward and obliquely upward of the crankshaft **30**. A counter shaft **71** located in left side of the crankshaft **30** is supported on a partitioning plane by being sandwiched between the upper and lower crankcases **31**U, **31**L at a position leftward and obliquely downward of the main shaft **61** (see FIG. **3**).

The main shaft **61** includes an inner cylinder **61***i* and an outer cylinder **61***o*, which rotatably fits on part of the inner cylinder **61***i*. The front end of the inner cylinder **61***i* is rotatably supported by a bearing recess **62** formed on a front wall **31***f* of the transmission chamber M of the upper crankcase **31**U with the intermediary of a first bearing **62***b*. The outer cylinder **61***o* is fitted on the inner cylinder **61***i* substantially at a center position on the rear side so as to be capable of relative rotation. Part of the outer cylinder **61***o* is rotatably supported by a bearing opening **63** formed on a rear wall **31***r* of the transmission chamber M with the intermediary of a second bearing **63***b* and is supported together with the inner cylinder **61***i*.

The outer cylinder **61***o* is integrally formed with a second transmission drive gear m2 and a fourth transmission drive gear m**4** at the front and rear respectively on a portion inside the second bearing **63***b*. The outer portion projects partly outward from the second bearing **63***b*.

On the inner cylinder **61***i*, a first transmission drive idle gear m**1**, a fifth transmission drive gear m**5** formed integrally with a shifter and spline-fitted to the inner cylinder **61***i*, and a third transmission drive idle gear m**3** in sequence from the front on the front side of the second and fourth transmission drive gears m**2** and m**4** on the outer cylinder **61***o* are rotatably supported. The outer portion of the inner cylinder **61***i* projects further rearward from the outer portion of the outer cylinder **61***o*.

The bearing recess **62** formed on the front wall **31***f* is formed to have a small inner diameter for rotatably supporting the front end of the inner cylinder **61***i* having a small diameter. The bearing opening **63** formed on the rear wall **31***r* is formed to have an inner diameter larger than the diameter of the fourth transmission drive gear m**4** at the rear end. The bearing opening **63** is used for assembly of the main shaft **61**.

The bearing opening **63** on the rear wall **31***r* of the transmission chamber M has an inner opening end formed with an inwardly extending flange **63***f* projecting slightly toward the center axis. The inner diameter of the flange **63***f* is larger than the diameter of the fourth transmission drive gear m**4**.

An input sleeve **65** is rotatably fitted on the outer portion of the inner cylinder **61***i* in juxtaposition with the outer cylinder **61***o*. The primary driven gear **56***b* is fitted at the center of the input sleeve **65**, so that the primary driven gear **56***b* meshes with the primary drive gear **56***a* on the side of the crankshaft **30**.

A first transmission clutch **66** is assembled to the input sleeve **65** at a position rearwardly of the primary driven gear **56***b*. A second transmission clutch **67** is assembled thereto at a position forwardly of the primary driven gear **56***b*. A pair of the first transmission clutch **66** and the second transmission clutch **67** are hydraulic multiple disc friction clutches having the same structure.

The first transmission clutch **66** includes a cup-shaped clutch outer **66***o* opening rearward integrally fitted to the input sleeve **65**, and a clutch inner **66***i* integrally fitted to the internal cylinder **61***i*. On the other hand, the second transmission clutch **67** includes a cup-shaped clutch outer **67***o* opening forward integrally fitted to the input sleeve **65** and a clutch inner **67***i* integrally fitted to the outer portion of the outer cylinder **61***o*.

When hydraulic pressure is supplied to the first transmission clutch **66** and hence the clutch outer **66***o* and the clutch inner **66***i* are connected, the rotation of the input sleeve **65** which is integral with the primary driven gear **56***b* is transmitted to the rotation of the second and fourth transmission drive gears m**2**, m**4** of the outer cylinder **61***o*. When hydraulic pressure is not supplied, the clutch outer **66***o* and the clutch inner **66***i* are disconnected and the rotation is not transmitted to the second and fourth transmission drive gears m**2** and m**4** of the outer cylinder **61***o*.

In the same manner, when the hydraulic pressure is supplied to the second transmission clutch **67** and hence the clutch outer **67***o* and the clutch inner **67***i* are connected, the rotation of the input sleeve **65** which is integral with the primary driven gear **56***b* is transmitted to the inner cylinder **61***i*. Hence, the fifth transmission drive gear m**5** spline-fitted to the inner cylinder **61***i* is rotated. When the hydraulic pressure is not supplied, the clutch outer **67***o* and the clutch inner **67***i* are disconnected. Hence, the rotation is not transmitted to the fifth transmission drive gear m**5** on the inner cylinder **61***i*.

The counter shaft **71** supported on a partitioning plane by being sandwiched between the upper and lower crankcases **31**U, **31**L at a position leftward and obliquely downward of the main shaft **61** as described above is rotatably supported at the front portion by a bearing opening **72** formed on the front wall **31***f* of the transmission chamber M via a bearing **72***b*, and is rotatably supported at the rear end thereof by a bearing recess **73** formed on the rear wall **31***r* of the transmission chamber M via a bearing **73***b*.

A first transmission driven gear n**1**, a fifth transmission driven idle gear n**5**, a third transmission driven gear n**3** formed integrally with the shifter and spline-fitted to the counter shaft **71**, a reverse idle gear nR, a second transmission driven idle gear n**2**, a shifter nS, a fourth transmission driven idle gear n**4** are arranged and supported rotatably by the counter shaft **71** via a shaft in sequence from the front in the transmission chamber M. The corresponding transmission drive gear and the transmission driven gear are constantly meshed with each other.

A reverse idle shaft **70** is disposed at a position above the counter shaft **71** (see FIG. **3** and FIG. **4**). A reverse large diameter gear r**1** and a reverse small diameter gear r**2** are supported by the reverse idle shaft **70** so as to rotate integrally. The reverse large diameter gear r**1** meshes with the second transmission drive gear m**2** on the main shaft **61**. The reverse small diameter gear r**2** meshes with the reverse idle gear nR on the counter shaft **71**.

The fifth transmission drive gear m**5** on the main shaft **61** and the third transmission driven gear n**3** on the counter shaft **71** are shifter gears. The two shifter gears and the shifter nS on the counter shaft **71** are shifted in the axial direction by the transmission drive mechanism so that the transmission speeds are achieved.

In other words, the first speed and the third speed are achieved by the fore-and-aft shifting of the fifth transmission drive gear m**5**. The fifth speed and reverse movement are achieved by the fore-and-aft shifting of the third transmission driven gear n**3**. The second speed and the fourth speed are achieved by the fore-and-aft shifting of the shifter nS. The switching control of the transmission speeds and the control of the first transmission clutch **66** and the second transmission clutch **67** cooperate to transmit the power in the respective transmission speeds.

The front end of the counter shaft **71** projects forwardly from the bearing **72***b*. An output gear **74** is spline-fitted to the front end. The output shaft **80** is disposed downwardly and obliquely rightward of the counter shaft **71** (see FIG. **3**). A driven gear **75** spline-fitted to the front portion of the output shaft **80** meshes with the output gear **74** at the front end of the counter shaft **71**, so that a power is transmitted from the counter shaft **71** to the output shaft **80**.

Since a larger load by the meshing between the output gear **74** and the driven gear **75** of the output shaft **80** is applied to the output gear **74** at the front end of the counter shaft **71**, the bearing **72***b* for rotatably supporting the front portion of the counter shaft **71**, which is employed here, is relatively large. Therefore, the inner diameter of the bearing opening **72** for fitting the bearing **72***b* of the front wall **31***f* is also large. However, since the bearing recess **62** of the adjacent main shaft **61** is small in diameter as descried before, the strength of the front wall **31***f* of the upper crankcase **31**U around the output gear **74** may be maintained at a high level.

A front case cover **85** covers the upper and lower crankcases **31**U, **31**L configured to be divided into upper and lower halves so as to extend across the partitioning plane on the front surface from which the counter shaft **71** and the output shaft **80** project. A rear case cover **150** covers the upper and lower crankcase **31**U, **31**L so as to extend across the partitioning plane on the rear surface of the crankcase **31**L and covers the fluid coupling **55** at the rear end of the crankshaft **30** and the first and second transmission clutches **66** and **67** at the rear ends of the main shaft **61** via a spacer **110** which also serves partly as a case cover.

The output shaft **80** is configured with a front end borne portion **81** and a rear end borne portion **82**, which are formed by casting and are connected by a hollow cylindrical member **83**. The front end borne portion **81** is rotatably supported by a bearing opening **86** formed on the front case cover **85** so as to penetrate through the through hole **76***f* formed on the front wall of the lower crankcase **31**L via a bearing **86***b* with the front end projecting forward from the front case cover **85**. The rear end borne portion **82** is rotatably supported by a bearing opening **111** formed on the spacer **110** so as to penetrate through the through hole **76***r* formed on the rear wall of the lower crankcase **31**L via a bearing **111***b* with the rear end projecting rearward from the spacer **110**.

In other words, the output shaft **80** is rotatably supported by the front case cover **85** and the spacer **110**, with the front end borne portion **81** and the rear end borne portion **82** projecting from the front and rear respectively. In particular, the front through hole **76***f* is adjacent to the front bearing opening **72** of the counter shaft **71**. The driven gear **75** is spline-fitted to the front end borne portion **81** adjacently inside a bearing **85***b*.

Therefore, the output gear **74** at the front end of the counter shaft **71** meshes with the driven gear **75** spline-fitted to the front end borne portion **81** of the output shaft **80**, so that power is transmitted from the counter shaft **71** to the output shaft **80**.

The crankshaft **30** and the counter shaft **71** are rotatably supported on the partitioning plane between the crankcases **31**U and **31**L oriented in the fore-and-aft direction configured to have the upper and lower halves. Therefore, the main shaft **61** is rotatably supported by the opposed front and rear walls of the upper crankcase **31**U, and the crankshaft **30**, the main shaft **61** and the counter shaft **71** are arranged at the respective apexes of a triangle. Therefore, the lateral width of the internal combustion engine may be reduced.

The output shaft **80** penetrates through the front and rear walls of the lower crankcase **31**L from between the upper and lower crankcases **31**U and **31**L by which the main shaft **61** is not rotatably supported, is rotatably supported by penetrating through the front case cover **85** and the spacer **110**, and projects to the front and rear. Therefore, the shaft support of the crankcase **31** may be dispersed, and hence the shaft support may be achieved desirably without upsizing the internal combustion engine E.

The output shaft **80** is configured with the front end borne portion **81** and the rear end borne portion **82**, which are formed by casting and are connected by the hollow cylindrical member **83**. Therefore, the weight of the output shaft **80** may be reduced, and a casting apparatus may be downsized in comparison with the case of casting and molding the entire output shaft as in the background art.

On the other hand, a balancer shaft **90** is rotatably supported by being sandwiched on the partitioning plane between the upper and lower crankcases **31**U and **31**L at a position rightwardly of the crankshaft **30** (see FIG. **3**).

Referring now to FIG. **5**, the balancer shaft **90** is rotatably supported at the front end and the rear end thereof by bearing openings **91** and **92** formed on the front wall and the rear wall of the upper and lower crankcases **31**U and **31**L via bearings **91***b* and **92***b*, respectively.

The balancer shaft **90** is arranged at a position as close as possible to the crankshaft **30**. As shown in FIG. **5**, balancer weights **90**W of the balancer shaft **90** overlap with (counter weights of) crank webs **30***w* of the crankshaft **30** in the direction of the crankshaft (fore-and-aft direction).

A driven gear **93** is spline-fitted to the bearing **91***b* fitted at the front end of the balancer shaft **90** adjacently inside the bearing **91***b*. The driven gear **93** meshes with the balancer shaft drive gear **54** fitted to the crankshaft **30** so that the rotation of the crankshaft **30** is transmitted to the balancer shaft **90** at the same revolving speed.

Therefore, primary vibrations caused by the reciprocal motion of the pistons **40** are cancelled by the rotation at the same speed as the crankshaft **30** of the balancer shaft **90**.

A water pump **95** provided on a front cover member **87** for covering the AC generator **57** or the like from the front is provided forwardly of the balancer shaft **90**. A water pump drive shaft **96** rotatably supported by a bearing cylinder **87***a* of the front cover member **87** is arranged coaxially with the balancer shaft **90**.

A connecting projection **90***f* projecting forward from the front end of the balancer shaft **90** and a connecting recess **96***a* formed at the rear end of the water pump drive shaft **96** are fitted so that the rotation of the balancer shaft **90** is transmitted to the water pump drive shaft **96** to drive the water pump **95**. The front side of the water pump **95** is covered with a water pump cover **97** provided with an intake cylinder **97***a*.

The intake cylinder **97***a* of the water pump cover **97** is connected by the radiator **27** and a water piping arranged on the front side of the vehicle body, so that the water pump **95** sucks cooling water from the radiator **27**.

On the other hand, an oil pump unit **100** provided on the spacer **110** is disposed rearwardly of the balancer shaft **90**. An oil pump drive shaft **101** that is rotatably supported by the oil pump unit **100** is arranged coaxially with the balancer shaft **90**.

A connecting recess **90***r* formed at the rear end of the balancer shaft **90**, and a connecting projection **101***a* projecting at the front end of the oil pump drive shaft **101** are fitted, so that the rotation of the balancer shaft **90** is transmitted to the oil pump drive shaft **101** to drive the oil pump unit **100**.

A dry sump system is employed for lubrication of the power unit P, and both rotors of a scavenge pump **102** and a feed pump **103** are mounted to the oil pump drive shaft **101** of the oil pump unit **100**.

A transmission drive mechanism **200** for performing shift transmission by shifting the shifter of the transmission gear mechanism **60** of the transmission T is provided below the crankshaft **30** and the main shaft **61**.

The lower portion of the rear case cover **150** is formed with a gear case portion, which accommodates a speed reduction gear mechanism therein, and is covered by a gear case cover **201** from behind. A transmission power motor **202** is mounted to the right side of the gear case cover **201** from behind. A shift spindle **206** is provided to the lower left portion thereof so as to penetrate through the front case cover **85**, the front and rear walls of the lower crankcase **31**L and the rear case cover **150**. An engaging portion **206***a* formed into the shape of a hexagonal column at the rear end thereof is projected rearward from the gear case cover **201** (see FIG. **3** and FIG. **6**).

Provided at the front end of the shift spindle **206** is an angle sensor **207** fixed to the front case cover **85**.

A first idle gear shaft **203** and a second idle gear shaft **204** are rotatably supported in the gear case. A small-diameter drive gear **202***a* formed on the motor drive shaft projecting forward from the gear cover **201** of the transmission power motor **202** meshes with a large-diameter gear **203***a* formed integrally with the first idle gear shaft **203**. A small-diameter gear **203***b* formed integrally with the first idle gear shaft **203** meshes with the large-diameter gear **204**a formed integrally with the second idle gear shaft **204**. A small-diameter gear **204**b formed integrally with the second idle gear shaft **204** meshes with a fan-shaped gear shift arm **205** fitted to the shift spindle **206**. Therefore, the speed reduction gear mechanism is configured.

Therefore, the drive of the transmission power motor **202** is decelerated via the speed reduction gear mechanism and rotates the shift spindle **206**.

A shift drum **210** is rotatably supported obliquely upwardly of the shift spindle **206** between the front and rear walls of the lower crankcase **31**L. Shift transmission means **208** is interposed between the shift spindle **206** and the shift drum **210**. The rotation of the shift spindle **111** rotates the shift drum **210** via the shift transmission means **208**.

As shown in FIG. **6**, respective shift pins of shift forks **215**a, **215**b and **215**c that are slidably supported by a guide shaft **215** are fitted in three ridges of the shift grooves formed on the outer peripheral surface of the shift drum **210**. The shift fork **215**a, which is guided along the shift groove by the rotation of the shift drum **210** shifting in the axial direction shifts the shifter gear (the fifth transmission drive gear m**5**) on the main shaft **61**. The shift forks **215**b and **215**c shift the shifter gear (the third transmission driven gear n**3**) on the counter shaft **71** and the shifter nS to change the combination of gears to be meshed with each other for shift transmission. The rotational angle of the shift drum **210** is detected by a shift position detector **211** provided in front of the shift drum **210** coaxially therewith.

With the transmission drive mechanism **200** described above, the drive of the transmission power motor **202** rotates the shift spindle **206** via the speed reduction gear mechanism, and the rotation of the shift spindle **206** rotates the shift drum **210** via the shift transmission means **208**, so that the shift forks **215**a, **215**b and **215**c are shifted by the rotation of the shift drum **210** for shift transmission.

Then, by engaging an operating portion of a hexagonal hole of a wrench, which is a rotating tool with an engaging portion **111**a in the shape of the hexagonal column of the shift spindle **206** projected rearward from the gear case cover **201**, and rotating the same along the surface of the rear case cover **150**, the shift spindle **206** may be rotated to achieve manual shift transmission.

Assembly of the transmission gear mechanism **60** in which the transmission is performed by the transmission drive mechanism **200** as mentioned above will be described below.

Since the counter shaft **71** is rotatably supported on the partitioning plane by being sandwiched between the upper and lower crankcases **31**U and **31**L, the counter shaft **71** may be assembled by being supported between the semicircular bearing opening **72** and the bearing recess **73** on the partitioning plane of the lower crankcase **31**L with the transmission driven gear group assembled to the counter shaft **71**, and the bearings **72**b and **73**b fitted thereto.

In contrast, since the main shaft **61** is rotatably supported by the bearing recess **62** of the front wall **31**f and the bearing opening **63** of the rear wall **31**r in the transmission chamber M of the upper crankcase **31**U, assembly of the main shaft **61** is achieved by using the bearing opening **63** having a large inner diameter.

In other words, in a state in which the transmission drive gear group is assembled to the main shaft **61**, the rear end of the main shaft **61** is firstly inserted into the bearing opening **63** of the rear wall **31**r from inside through the opening on the partitioning plane of the transmission chamber M of the upper crankcase **31**U. Then, the fourth transmission drive gear m**4** at the rear end is inserted through the bearing opening **63** (in the inwardly extending flange **63**f) having a larger inner diameter, and then the front end of the main shaft **61** is inserted into the transmission chamber M, and is press-fitted into an inner lace of the first bearing **62**b having an outer lace fitted in advance to the bearing recess **62** of the front wall **31**f with the shaft center adjusted, so that the front end of the main shaft **61** is rotatably supported.

The second bearing **63**b is fitted into the bearing opening **63** from behind with the rear portion of the main shaft **61** projected rearward from the bearing opening **63** of the rear wall **31**r passed therethrough.

At this time, the outer race of the second bearing **63**b is fitted into the bearing opening **63**. At the same time, the inner race is fitted into the outer cylinder **610** of the main shaft **61**, whereby the outer cylinder **610** is rotatably supported together with the inner cylinder **61**i. The second bearing **63**b is fitted into the bearing opening **63** until it abuts against the inwardly extending flange **63**f.

In this manner, the main shaft **61** is rotatably supported by the bearing recess **62** of the front wall **31**f and the bearing opening **63** of the rear wall **31**r via the first and second bearings **62**b and **63**b, a thing in which the first transmission clutch **66** and the second clutch **67** are assembled to the input sleeve **65** and the primary drive gear **56**b is assembled, is mounted to the portion projecting rearward from the second bearing **63**b of the main shaft **61**, and a nut **69** is screwed into the rear portion of the outer cylinder **61**o via a washer **68**.

As described thus far, the bearing opening **63** for rotatably supporting the rear end of the main shaft **61** via the second bearing **63**b is formed on the rear wall **31**r so as to have a larger inner diameter than the fourth transmission drive gear m**4** at the rear end on the main shaft **61**. Therefore, the bearing opening **63** of the rear wall **31**r of the upper crankcase **31**U is used as an opening for assembling the main shaft **61**, so that the main shaft **61** having the transmission gear group assembled thereto may be inserted into the bearing opening **63** to achieve assembly of the main shaft **61** and the assembleability of the main shaft **61** is desirably secured.

Therefore, it is not necessary to use the bearing recess **62** for rotatably supporting the front end of the main shaft **61** via the first bearing **62**b at one end as the opening for assembling the main shaft and hence the inner diameter may be reduced, and the bearing recess **62** having a small inner diameter for rotatably supporting the front end of the inner cylinder **61**i of the main shaft **61** having a small diameter is employed. Therefore, even when the bearing opening **72** for rotatably supporting the counter shaft **71** formed in adjacent thereto is formed to have a large diameter for fitting the large bearing **72**b for resisting a load applied to the output gear **74**, the strength of the side wall of the upper crankcase **31**U in the periphery of the output gears **74** may be maintained at a high level.

Also, after having assembled the main shaft **61** to the upper crankcase **31**U, the pair of transmission clutches **66** and **67** may be assembled to the outer portion of the outer cylinder **61**o and the outer portion of the inner cylinder **61**i projecting outward from the upper crankcase **31**U, and hence the assembly of the transmission clutches **66** and **67** may be achieved easily.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. A crankcase structure of an internal combustion engine, comprising:

a crankcase including upper and lower halves;

a crankshaft and a counter shaft rotatably supported on a partitioning plane of the crankcase and oriented in the fore-and-aft direction;

a main shaft oriented in the fore-and-aft direction and rotatably supported on opposed front and rear walls of one of the upper and lower halves of the crankcase; and

an output shaft oriented in the fore-and-aft direction to be driven by power of the counter shaft,

wherein the output shaft penetrates through the front and rear walls of the other of the upper and lower halves of the crankcase, which does not support the main shaft, and projects to the front and rear.

2. The crankcase structure of an internal combustion engine according to claim **1**, further comprising:

a bearing opening for rotatably supporting the counter shaft via a bearing, said bearing opening being formed on one side wall of the crankcase at a position in the proximity of an output member provided at an end of the counter shaft that projects outward from one of the opposed front and rear walls of the crankcase;

a first bearing recess for rotatably supporting one end of the main shaft via a first bearing, said first bearing recess being formed on said one side wall of the crankcase adjacent to the bearing opening for rotatably supporting the counter shaft; and

a second bearing recess for rotatably supporting the other end of the main shaft via a second bearing, said second bearing recess being formed on the other side wall of the crankcase, which opposes the one side wall of the crankcase,

wherein said second bearing recess has a larger inner diameter than a transmission gear located at an outer most end of the other end of the main shaft.

3. The crankcase structure of an internal combustion engine according to claim **2**, wherein the main shaft includes an inner cylinder and an outer cylinder rotatably fitted to a part of the inner cylinder, one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the other end of the inner cylinder is rotatably supported together with the outer cylinder by the second bearing recess on the other side wall via the second bearing.

4. The crankcase structure of an internal combustion engine according to claim **3**, wherein the main shaft is inserted into the second bearing recess on the other side wall of the crankcase, and the one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the second bearing is fitted between the outer cylinder rotatably fitted to a predetermined position of the inner cylinder and the second bearing recess of the other side wall from the outside, so that the main shaft is assembled.

5. The crankcase structure of an internal combustion engine according to claim **3**, wherein a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder, respectively, are assembled respectively to the outside portion of the outer cylinder that projects outward from the second bearing recess of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

6. The crankcase structure of an internal combustion engine according to claim **4**, wherein a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder, respectively, are assembled respectively to the outside portion of the outer cylinder that projects outward from the second bearing recess of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

7. The crankcase structure of an internal combustion engine according to claim **1**, further comprising:

a first bearing recess for rotatably supporting one end of the main shaft via a first bearing, said first bearing recess being formed on one side wall of the crankcase; and

a second bearing recess for rotatably supporting the other end of the main shaft via a second bearing, said second bearing recess being formed on the other side wall of the crankcase, which opposes the one side wall of the crankcase,

wherein said second bearing recess has a larger inner diameter than a transmission gear located at an outer most end of the other end of the main shaft.

8. The crankcase structure of an internal combustion engine according to claim **7**, wherein the main shaft includes an inner cylinder and an outer cylinder rotatably fitted to a part of the inner cylinder, one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the other end of the inner cylinder is rotatably supported together with the outer cylinder by the second bearing recess on the other side wall via the second bearing.

9. The crankcase structure of an internal combustion engine according to claim **8**, wherein the main shaft is inserted into the second bearing recess on the other side wall of the crankcase, and the one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the second bearing is fitted between the outer cylinder rotatably fitted to a predetermined position of the inner cylinder and the second bearing recess of the other side wall from the outside, so that the main shaft is assembled.

10. The crankcase structure of an internal combustion engine according to claim **9**, wherein a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder, respectively, are assembled respectively to the outside portion of the outer cylinder that projects outward from the second bearing recess of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

11. A crankcase structure of an internal combustion engine, comprising:

a crankcase including upper and lower halves;

a main shaft rotatably supported on one of the upper and lower halves of the crankcase; and

an output shaft, said output shaft penetrating the other of the upper and lower halves of the crankcase.

12. The crankcase structure of an internal combustion engine according to claim **11**, further comprising:

a bearing opening for rotatably supporting a counter shaft via a bearing, said bearing opening being formed on one side wall of the crankcase at a position in the proximity of an output member provided at an end of the counter shaft that projects outward from one of opposed front and rear walls of the crankcase;

a first bearing recess for rotatably supporting one end of the main shaft via a first bearing, said first bearing recess being formed on said one side wall of the crankcase adjacent to the bearing opening for rotatably supporting the counter shaft; and a second bearing recess for rotatably supporting the other end of the main shaft via a second bearing, said second bearing recess being formed on the other side wall of the crankcase,

wherein said second bearing recess has a larger inner diameter than a transmission gear located at an outer most end of the other end of the main shaft.

13. The crankcase structure of an internal combustion engine according to claim **12**, wherein the main shaft includes an inner cylinder and an outer cylinder rotatably fitted to a part of the inner cylinder, one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the other end of the inner cylinder is rotatably supported together with the outer cylinder by the second bearing recess on the other side wall via the second bearing.

14. The crankcase structure of an internal combustion engine according to claim **13**, wherein the main shaft is inserted into the second bearing recess on the other side wall of the crankcase, and the one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the second bearing is fitted between the outer cylinder rotatably fitted to a predetermined position of the inner cylinder and the second bearing recess of the other side wall from the outside, so that the main shaft is assembled.

15. The crankcase structure of an internal combustion engine according to claim **13**, wherein a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder, respectively, are assembled respectively to the outside portion of the outer cylinder that projects outward from the second bearing recess of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

16. The crankcase structure of an internal combustion engine according to claim **14**, wherein a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder, respectively, are assembled respectively to the outside portion of the outer cylinder that projects outward from the second bearing recess of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

17. The crankcase structure of an internal combustion engine according to claim **11**, further comprising:

a first bearing recess for rotatably supporting one end of the main shaft via a first bearing, said first bearing recess being formed on one side wall of the crankcase; and

a second bearing recess for rotatably supporting the other end of the main shaft via a second bearing, said second bearing recess being formed on the other side wall of the crankcase, which opposes the one side wall of the crankcase,

wherein said second bearing recess has a larger inner diameter than a transmission gear located at an outer most end of the other end of the main shaft.

18. The crankcase structure of an internal combustion engine according to claim **17**, wherein the main shaft includes an inner cylinder and an outer cylinder rotatably fitted to a part of the inner cylinder, one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the other end of the inner cylinder is rotatably supported together with the outer cylinder by the second bearing recess on the other side wall via the second bearing.

19. The crankcase structure of an internal combustion engine according to claim **18**, wherein the main shaft is inserted into the second bearing recess on the other side wall of the crankcase, and the one end of the inner cylinder is rotatably supported by the first bearing recess on the one side wall via the first bearing, and the second bearing is fitted between the outer cylinder rotatably fitted to a predetermined position of the inner cylinder and the second bearing recess of the other side wall from the outside, so that the main shaft is assembled.

20. The crankcase structure of an internal combustion engine according to claim **19**, wherein a pair of transmission clutches for controlling transmission of power to the outer cylinder and the inner cylinder, respectively, are assembled respectively to the outside portion of the outer cylinder that projects outward from the second bearing recess of the other side wall and the outside portion of the inner cylinder that projects further outward from the outer cylinder.

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